FOREST HISTORY OF OHIO. I. RADIOCARBON DATES AND POLLEN STRATIGRAPHY OF SILVER LAKE, LOGAN COUNTY, OHIO[1]

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ABSTRACT

Radiocarbon and pollen analysis of a sediment core (8.9 m) from Silver Lake in central Ohio indicates that deposition began in late Woodfordian time (11,000–14,000 radiocarbon years ago) and has been continuous to the present. The pollen sequence includes a basal spruce-fir pollen zone, changing abruptly to oak-elm immediately above a radiocarbon date of 9800±210 (OWU–39). A total of 19 radiocarbon dates document the climatic and environmental changes inferred from the sediment record. The Xerothermic interval of Sears (1942c) within the Hypsithermal (Deevey and Flint, 1957) is bracketed by radiocarbon dates (1300–3600 years, B.P.) and a distinct minimum in beech pollen. The presence of *Zea* pollen stratigraphically lower than the sharp rise in *Ambrosia* pollen which marks the advent of European settlers is believed to indicate pre-colonization Indian agriculture.

INTRODUCTION

The pioneering studies of Sears (1930, 1931, 1932, 1935, 1941) and those of his students (Smith, 1940; Potter, 1947) on the vegetational history of northern Ohio, led Sears (1942a, 1948) to develop a five-fold division of post-glacial time for this region. These divisions, or pollen zones, consisted of a basal spruce-fir pollen zone (I); an overlying pine pollen zone (II); a beech-mixed deciduous zone (III); an oak-hickory-prairie zone (IV); and a mixed deciduous zone (V) at the top. A similar five-fold division of post-glacial time was worked out by Krauss and Kent (1944) from four bogs in New Hampshire. Deevey (1939, 1943) recognized a similar sequence for Connecticut and southern New England and formalized the pollen zones with the letter "A" for the basal spruce-fir pollen zone, "B" for the overlying pine pollen zone, and "C" for the oak pollen zone. Three subdivisions of the "C" zone are recognized: C_1 is oak-hemlock, C_2 is oak-hickory, and C_3 is oak-chestnut. These divisions have found acceptance and are in use in most New England pollen diagrams at present. Eastern North American pollen zones are broadly similar to those of the Blytt-Sernander postglacial climatic sequence for northwestern Europe. A correlation table of North American and European pollen chronologies may be found in Deevey and Flint (1957). With the application of radiocarbon dating to pollen-stratigraphic events, it has become clear that postglacial climatic changes were approximately synchronous on both sides of the Atlantic Ocean. World-wide synchroneity of climatic history has yet to be demonstrated.

Climatic inferences derived from pollen analyses are predicated upon the recognition of approximately equivalent vegetational elements from modern floras. Attempts to relate existing vegetational elements to pollen floras quantitatively have proved disappointing (Davis and Goodlett, 1960; Davis, 1963). The similarity of pollen profiles from all of eastern North America has resulted in the interpretation of the basal spruce-fir pollen zone as indicating a cool-moist environment similar to that now found in the boreal forest region of northern Canada. The overlying pine pollen zone is interpreted to indicate a cool-dry environment. The vegetational interpretation of the pine zone is obscure, but Davis and Goodlett (1960) were able to show that less than 1% of pine in the forests surrounding Brownington Pond in Vermont were sufficient to produce as much as 20% of the total pollen flora in the surface muds of the lake. The pollen zones which include

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such warmth-demanding species as oak, hickory, elm, beech, walnut, and basswood are interpreted as indicating a warm environment with minor oscillations of temperature, or moisture, or both. There is considerable evidence (Sears, 1942c; Deevey and Flint, 1957) of a period of maximum warmth about 3000 years ago, which is marked by a dominance of oak and hickory in pollen profiles from northeastern United States (Deevey, 1939, 1943) and by the extension of prairie eastward into Indiana and Ohio (Gleason, 1923; Transeau, 1935).

Within broad limits, the succession in pollen spectra shown in profiles from eastern North America is believed to represent the migration of vegetational types northward as the glaciers receded. There is no question that boreal forest elements existed in Ohio, at least as far south as Lancaster, Chillicothe, and Cincinnati during the glacial periods. Goldthwait (1958) was able to determine the rate of advance of the glaciers southward through Ohio from radiocarbon dates of wood found in the till. Identification of these woods by Burns (1958) indicates the presence of spruce, larch, fir, and birch, which are today found far to the north of their fossil localities. Many of the trees were alive at the time they were "bulldozed" by the advancing glacier ice. In an elegant study of the tree rings of these bulldozed specimens, Burns (1956) was able to show a decrease in annual ring width as the ice approached and finally overwhelmed the trees. Braun (1928) has listed the occurrence of arbor vitae (*Thuja occidentalis*), *Betula pumila*, *Rhamnus alnifolia*, *Taxus canadensis*, and *Maianthemum canadense* in Cedar Swamp, Champaign Co., Ohio, as boreal relicts, dating from a period of cooler climate in the past.

Although the approximate forest sequence in postglacial time is reasonably clear, there is little vegetational record of the arctic tundra at the time of maximum ice advance. The first record of treeless conditions in North American pollen diagrams came from northern Maine, where Deevey (1951) demonstrated the presence of sedge and grass pollen types stratigraphically lower, and therefore older, than the first spruce pollen maximum. Subsequent investigations in southern New England by Leopold (1956), Davis (1958, 1960a), and Ogden (1959, 1963) demonstrated the occurrence of high-arctic pollen types whose present distribution is restricted to the arctic tundra.

No evidence of tundra has thus far been recovered in Ohio. West (1961) has demonstrated the presence of periglacial vegetation in analyses of three deposits in eastern Wisconsin which are related to the Valders ice readvance. Guilday (1963) has shown that the collared lemming (*Dicrostonyx hudsonius*) and the yellow-cheeked vole (*Microtus xanthognathos*), both of which are now restricted to the arctic tundra in northern Labrador and north and west of Hudson's Bay, lived in Pennsylvania during the Wisconsin age, just to the south of the Wisconsin ice border. Most of the pollen sequences described from Ohio and neighboring states, however, have ignored the nonarboreal pollen constituents. Pollen diagrams based on tree pollen alone can hardly be expected to reveal evidence of treeless conditions.

In the discussion which follows, three specific problems will be considered: a) the nature of the environments which developed in the wake of the retreating ice; b) the evidence for a warm-dry maximum, or xerothermic interval; and c) the evidence for forest disturbance by European agriculture and prior forest disturbance by Indians.

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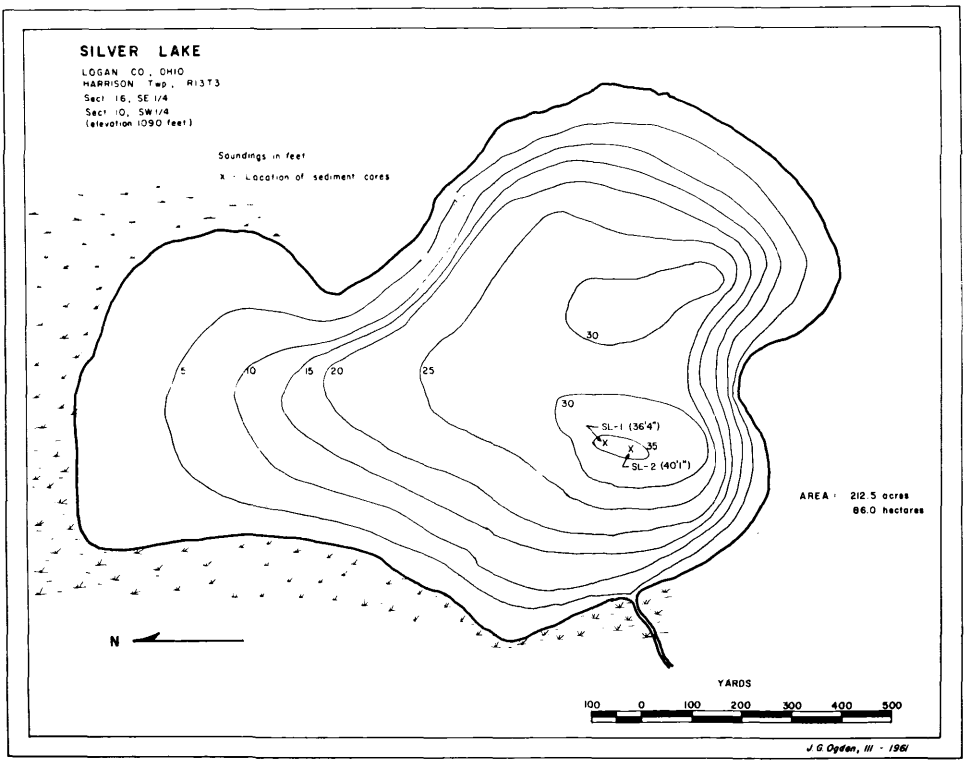

FIGURE 1. Shape and bathymetry of Silver Lake. Camp Willson and woodland located along north and east sides of lake. Soundings logged by traverse with a Heath M1–10 Depth Sounder.

LOCATION

Silver Lake, Ohio, is located approximately 7 miles southwest of the city of Bellefontaine (Bellefontaine, Ohio 15' quad., Logan Co., Harrison twp. R14W, T3N, Sects. 10 and 16) (fig. 1; fig. 2, no. 7). The shape and bathymetry of the lake are shown in figure 2. The basin of the lake is apparently a compound kettle, formed during the retreat of the ice from the Farmersville moraine in which the lake lies. The elevation of the lake is 1090 feet, MSL.

VEGETATION

The area around the lake is extensively cultivated, primarily in corn and cereal grasses. Aerial photographs reveal (by planimetry) that less than 10% of the land within a radius of five miles of the lake is in woodland. High-grading and clear-cutting have removed all of the original forest vegetation. The woodland

on the east side of Silver Lake is unique in this respect, however, as approximately 50 acres of land have been protected for at least 100 years from the effects of cutting. Within this stand are some of the most remarkable oaks, hickories, and wild black cherry trees to be found in Ohio. Several specimens of white oak (*Quercus alba*) measured more than 40 inches DBH (Diameter Breast High), and one gigantic wild black cherry tree measured 57.3 inches DBH (15.1 feet circumference). The size of this tree equals or exceeds the wild black cherry at Rocky Fork Park, Ohio, and may therefore be a record tree.

The history of this woodland deserves comment, since it is one of the oldest stands of trees in the state, and represents an early but effective method of conservation. Most of the following discussion was derived from conversations with Mr. C. H. Klippel, a director of Camp Willson, the Y.M.C.A. summer camp at Silver Lake. The previous owner of the farm on which this woodland is located devised a simple, but effective scheme to protect his trees. He drove barn spikes, each one about 1 inch in diameter and 15 inches long, into many of the trees

TABLE 1

Basal area, relative density, and frequency of tree species, Camp Willson, Silver Lake, Ohio

Species	Basal area ft²/acre	Relative density	Frequency %
Quercus alba	25.0	21.8	75
Prunus serotina	23.7	20.6	69
Robinia pseudoacacia	10.6	9.3	25
Ulmus rubra	10.0	8.7	31
Carya ovata	8.8	7.6	44
C. glabra	7.5	6.5	44
Juglans nigra	7.5	6.5	44
Acer saccharinum	5.0	4.3	13
Crataegus spp.	4.4	3.8	31
Quercus velutina	3.8	3.3	25
Q. rubra	3.1	2.7	25
Platanus occidentalis	2.5	2.2	25
Ulmus americana	1.2	1.1	13
Quercus prinus	1.2	1.1	6
Populus deltoides	0.6	0.5	6
Σ Quercus spp.	33.1	28.9	78
Σ Carya spp.	16.3	14.1	59

Σ Basal area for all species—114.7 ft²/acre.

growing on his land. In some he put two, or even three spikes. In the course of time, the trees overgrew the spike heads, effectively concealing the location and number of spikes. Although all of the commercial sawyers in the district know of these handsome trees, none will touch a saw to the stand, for fear of striking one of the spikes. A sawmill blade, impinging on one of the spikes, would shatter with grave, if not fatal, consequences to the sawyer. It is suggested here that this device may be more effective than all of the educational publicity put out in behalf of conservation.

Table I lists the principal components of the woody vegetation, omitting shrubs and vines. Nomenclature follows Gray's Manual of Botany, 8th Ed.

(Fernald, 1950). Plotless measurements were taken, using a Bitterlich stick as outlined in Phillips (1959). The amount of wild black cherry (*Prunus serotina*) is perhaps the most striking feature of this stand. The fact that cherry comprises almost 21% of the trees tallied indicates a secondary origin even for this very old stand. Although most of the cherry trees are in the 12–18″ DBH class, there are a few which exceed 30″ DBH, including the giant described earlier. The hickories (*Carya ovata* and *C. glabra*) generally range from 30–40 inches DBH, while the white oaks (*Quercus alba*) and black oaks (*Q. velutina*) are substantially larger, 40–50″ DBH. A few sycamores (*Platanus occidentalis*) near the lake margin approach these sizes, with diameters in the 30–40-inch DBH class. One large specimen of red maple (*Acer rubrum*), just outside the sampling area, had a stem diameter of 35.1 inches DBH.

The activity of the Y.M.C.A. camp maintains the forest floor in a state of active turmoil, resulting in a flora that is as uncharacteristic of the trees towering above it, as it is difficult to walk through. The most prominent members of the shrub community are: *Ribes cynosbati*, *Rhus toxicodendron*, *Rubus occidentalis*, *Laportea canadensis* (up to 8 feet in height), *Smilax rotundifolia*, and *S. hispida*. Less abundant, but distinctly more pleasant to walk through, are patches of *Lindera benzoin*, *Viburnum lentago*, and *Cornus florida*. *Vitis cordifolia* is not abundant, but 3–4-inch stems can be found on some of the smaller (12–18-inch DBH) trees. *Ostrya virginiana* is found throughout the woods, but none of the specimens were large enough to tally with the Bitterlich stick.

The herbaceous flora includes dense stands of *Galium circaezans*, *Osmorrhiza Claytoni*, and *Ambrosia trifida*, with *Taraxacum officinale* lining the paths. In the few relatively untrampled spots, such characteristic oak-hickory community species such as *Viola palmata*, *Potentilla canadensis*, *Solidago canadensis*, *Agrostis alba*, *Lobelia inflata*, *Scrophularia nodosa*, *Acalypha gracilens*, *Pilea pumila*, and *Danthonia spicata* are found. It is quite obvious from the foregoing list that the herbaceous community does not reflect the original character of the forest floor. For this reason, no detailed study was made of the herbaceous communities. Other species encountered at sampling stations were: *Podophyllum peltatum*, *Parthenocissus quinquefolia*, *Smilacina racemosa*, *Impatiens pallida*, *Caulophyllum thalictroides*, *Polygonatum biflora*, *Aster* spp., *Potentilla fruticosa*, *Geum canadense*, *Actaea rubra*, and *Erigeron ramosus*.

The presence of large numbers of mature trees and seedlings of black locust (*Robinia pseudoacadia*), honey locust (*Gleditsia triacanthos*), and hawthorne (*Crataegus*, spp.), also indicates a long history of disturbance, possibly by grazing. Seedlings of the oaks, hickories, and cherries are frequently found in openings caused by the blow-down of one or more of the large oaks or hickories. A few of these large trees have provided Camp Willson with ample firewood for several years. It was in connection with cutting up one of the downed trees that the history of spiking was discovered, fortunately without the grave consequences mentioned previously. The stumps of the downed trees show little sign of internal decay, although some of the larger standing cherries show signs of heart-rot. Ring counts of 250 and 285 were observed on two white oak stumps.

Beech-maple stands are almost non-existent in Logan County (Forest Resources of Logan County, 1935). In many of the farm woodlots in the county, white ash (*Fraxinus americana*) and American elm (*Ulmus americana*) equal oak and hickory as dominants. Ash and elm are found mostly as successional stages following clear-cutting. Near DeGraff, Ohio, about 5 miles southwest of Silver Lake, several specimens of mossycup oak (*Quercus macrocarpa*) were observed. The stem diameter of these trees measured between 24–36 inches DBH.

It seems quite probable, from the disturbed character of the shrub and herb layers of the Silver Lake woods, that grazing has occurred until rather recent times, possibly until the establishment of the Y.M.C.A. camp about 20 years ago.

POLLEN ANALYSIS

Methods. Two cores have been recovered from Silver Lake, using a modified Livingstone piston sampler. Core samples were sealed in the field and kept under refrigeration until analysis was begun in the laboratory. Techniques for extraction and concentration of pollen grains have been outlined in Ogden (1959). The borings extended into till; pollen samples were recovered from the till. The results of the pollen and chemical analysis of core SL–1 are summarized in three diagrams:

Plate I—SL–1A. Percentage Base=Σ Pollen, exclusive of the pollen of aquatic plants, spores, and other microfossils. Radiocarbon dates are shown to the left of the diagram, and described in detail in Table II.

Plate II—SL–1B. Percentage Base=Σ Pollen. This diagram includes all pollen types lumped under "Σ Miscellaneous NAP," in SL–1A, plus aquatic plant pollen and non-pollen microfossils (expressed as a percentage of the total pollen at each level).

Plate III—SL–1C. Percentage Base=Arboreal pollen. This diagram is prepared to facilitate comparison of this deposit with earlier analyses in which only arboreal pollen was considered. Shrubs and herbs are expressed as a percentage of total tree pollen at each level.

Sediment Stratigraphy. Color, texture, and composition of the sediments at the top and bottom of each 1 meter core sample were recorded in the field. The remainder of the stratigraphy was recorded when the cores were extruded for analysis in the laboratory. The depth of water for core SL–1 was 11.02 m. No adjustment was made for core loss, because 95–100 cm was recovered for each 1 m core sample.

Core depth cm	Sediment
0– 65	flocculent to coherent yellow-green marly gyttja
65–230	homogeneous dark gray-green gyttja with marl banding
230–260	light gray marly gyttja
260–330	homogeneous dark gray-green gyttja
330–345	banded marly light gray-green gyttja
345–385	banded dark gray-green marly gyttja
385–410	homogeneous light gray-green marly gyttja
410–675	homogeneous dark gray-green gyttja
675–715	marly clay gyttja with some silt
715–750	stiff yellow-brown clay gyttja
750–775	dark gray clay gyttja with medium fine sand and silt
775–865	light gray clay gyttja with some silt
865–890	compact gray clay till with coarse sand and calcareous gravel.

Loss on ignition data (600°C.) and carbonate analysis (CO_3=determined as calcium+magnesium by titration with ethylene diaminetetraacetic acid) are shown in Plate II.

Discussion. The main block diagram at the left in Plate I indicates the major pollen components of core SL–1. Significant radiocarbon dates are indicated, together with the thickness of sediment used to obtain the sample. Radiocarbon dates are from core SL–2, and the samples are controlled at each level by sediment stratigraphy and comparison of pollen spectra from each radiocarbon sample. The pollen zone numbers designated in the diagram are included only to simplify discussion of the diagrams. It is considered that zone 1 indicates an environment suitable for spruce and fir forests, that zone 2 is transitional, and that zone 3 indicates an environment dominated by deciduous trees. Subdivisions of these zones are only for convenience, and chronologic equivalence of these zone numbers with other pollen sequences from Ohio and Ontario is not implied.

The term "late-glacial" has been used in different contexts by various writers. Deevey and Flint (1957) use the term as a time-stratigraphic unit, including as late-glacial all vegetational records prior to 10,500 years, B. P. West (1961) used the term to describe vegetational records indicating the presence of treeless regions in the vicinity of the deposit and the presence of cold-climate open-country indi-

cators among the non-arboreal pollen. To avoid confusion, the term "periglacial" will be used to indicate high-arctic environments represented in SL–1.

Pollen zone 1. Evidence for periglacial conditions at the base of SL–1 is restricted to the presence of sedge and grass pollen (13% and 9% respectively, of the pollen flora), and such open country indicators as *Saxifraga oppositifolia* and *Polygonum bistorta*, of which Polunin (1959) states, "restricted to open ground and well-drained grassy areas." In the absence of fruits or seeds from these plants, and because of the uncertainty of specific identification from pollen alone, the existence of a true arctic tundra cannot be established from this evidence.

TABLE 2

Radiocarbon determinations on sediments from Silver Lake, Ohio

	Depth	Pollen Zone	Sample no.	Material	Uncorrected age	Corrected average age	Average depth
A	0–10		OWU–30	organic	1186±161		
	10–20		OWU–31	organic	821±84		
	0–15	3d	OWU–72	marl CO_3	829±62	980*=0	0–15
	0–15		OWU–72A	organic	1353±66		
	0–15		OWU–73A	organic	725±172		
B	60–70		OWU–38	organic	1306±107	260±108	75
	80–90		OWU–40	organic	1182±105		
	100–110		OWU–41	organic	1753±189		
	120–130	3c	OWU–46	organic	1525±92	650±210	125
	140–150		OWU–47	organic	1618±201		
	160–170	—	OWU–48	organic	2152±260	1160±250	185
	200–210		OWU–55	organic	2122±184		
	220–230	3b	OWU–77	organic	2290±423	1310±423	205
	340–350	—	OWU–79	organic	4479±212	3600±212	345
	400–410		OWU–57	organic	5033±217	5090±265	425
	440–450	—	OWU–80	organic	7104±260		
	500–510		OWU–58	organic	5295±232	6150±340	525
	540–550	—	OWU–81	organic	8960±335		
	600–615	2	OWU–39	organic	10778±210	9800±210	610

A. *980 years subtracted from all core sample determinations as an estimate of the contribution of Paleozoic carbonate to the lake system.

B. Average dates calculated according to the following:

$$\frac{X_1+X_2}{2} - 980 = \text{Average sample age}$$

$$\text{mean deviation} = \sqrt{\frac{(\sigma X_1)^2 + (\sigma X_2)^2}{2}}$$

An increase in forest cover is implied by the decline in both sedge and grass pollen in zone 1. It is not possible to estimate how much open country would be represented by the pollen spectra below 800 cm, where tree pollen is approximately 70%, but as will be discussed in detail later, the surface pollen spectra of the lake show approximately 50% arboreal pollen, while measurements from aerial photographs indicate that less than 10% of the land within five miles of the lake is in woodland.

In an attempt to recognize the nature of the forest vegetation indicated by the pollen record of zone 1, a field trip to northern Ontario was undertaken in the

summer of 1961. Surface pollen samples from lakes and vegetation around the lakes were studied under a National Science Foundation Undergraduate Research Participation grant. Although detailed results of these studies are to be described elsewhere, it is sufficient to note here that the pollen spectra in zone 1 of the Silver Lake core resemble the surface pollen spectra recovered from lakes in the Cochrane-Iroquois Falls area of northern Ontario. Correlation coefficients determined for surface pollen samples from northern Ontario and from 800 cm in core Sl–1 show a high correlation ($r = .895$). This region is known as the Northern Clay Forest Section (Rowe, 1959) and has been described in detail by MacLean (1962).

The forests of this Ontario region are predominantly black spruce (*Picea mariana*), with some white spruce (*P. glauca*) and balsam fir (*Abies balsamea*) on better drained sites. Aspen (*Populus tremuloides*) and birch (*Betula lutea*) are found in association with the white spruce and fir. Jack pine (*Pinus banksiana*) is restricted to sandy ridges, such as old beaches and offshore bars in former glacial lake beds.

The low frequencies of pine, birch, fir, and aspen pollen shown in zone 1 are in agreement with a vegetation similar to the existing black spruce forest types of the Abitibi region of northern Ontario.

These observations indicate that sedimentation did not begin in Silver Lake until some time after the ice had retreated from the Farmersville position. It seems quite clear that plant succession leading to a closed boreal forest community was well advanced by the time Silver Lake began to accept the local pollen rain.

A single pollen sample was recovered from the till and is presented as a bar graph at 885 cm. This sample does not differ markedly from the pollen spectra immediately overlying it, indicating that some mixing of the lowermost organic samples with the till may have taken place. Spores, principally "Tasmanites" (K. H. Clisby, personal communication), predominate in the till, and were found occasionally in spectra from zones 1 and 2. The pollen curve shown as "Redeposited Pollen" in Plate I includes these, and other oxidized and fragmented grains which may have been contemporaneous with the pollen spectra with which they are associated, but which are considered to be secondary in origin, possibly by redeposition from the surrounding uplands.

Pollen zone 2. A return to open-country conditions is indicated by the abrupt decline of spruce pollen and the sharp rise of nonarboreal pollen. The increase in oak and pine pollen shown in this zone may be more apparent than real. The decrease in spruce pollen has the effect of removing a masking effect from the oak and pine pollen, whose absolute numbers do not increase very markedly in this zone. In other words, it would appear that there is a real decrease in tree pollen production near the site, thereby increasing the contribution of distantly derived pollen types. The nonarboreal pollen maximum consists principally of sedge and grass pollen.

The meaning of the oak maximum in zone 2 is obscure, but a similar rise in oak pollen can be found at the spruce-oak transition in the southwestern Ontario bogs studied by Wilson and Webster (1943) and in Seidel Lake, Wisconsin (West, 1961), and is a prominent feature of the pollen sequences of Kokomo Bog and Jeff Bog (fig. 2, nos. 2 and 3), Indiana (Potzger, 1946). A pre-pine-zone maximum of oak pollen may also be seen in Engelhardt's (1960) analysis of Fox Prairie Bog and Bacon's Swamp, Indiana (fig. 2, no. 3), and in the Myers Lake diagram of Frey (1959). Sears (1942a) and Potter (1947) found a similar sequence in Long Lake Bog (fig. 2, no. 10), Granger Bog (fig. 2, no. 12), Camden Bog (fig. 2, no. 11), and Bucyrus Bog (fig. 2, no. 8) in northern Ohio.

If these pollen events are synchronous, then the oak-pollen maximum immediately above the spruce-pollen maximum must be post-Valders by an amount of time sufficient to melt the ice blocks which formed the kettles in which the pollen records of Seidel Lake (West, 1961) were deposited. On the other hand, if these

events are not synchronous, the similarity of these records indicates a similar ecological history, the elucidation of which must await further study.

The lack of radiocarbon dates from these deposits makes it difficult to determine which of the above interpretations is correct. It is unlikely, however, that the climatic amelioration which permitted the accumulation of the pollen record in Seidel Lake, Wisconsin, would have occurred at the same time in central Indiana and Ohio. If this were the case, then glacier ice would have had to have been present in Indiana and Ohio during this time. Radiocarbon dates from postglacial materials in northern and central Ohio shown in Figure 2 and described in Table III preclude the possibility of ice in the vicinity of Silver Lake during zone-2 time. Further, Disterhaft Farm Bog (West, 1961), which lies outside the Valders end moraine in Wisconsin, does not show this sequence.

Sedimentation rates calculated from core segments of the Silver Lake core indicate a mean sediment accumulation rate of 4.3 cm per century. The NAP

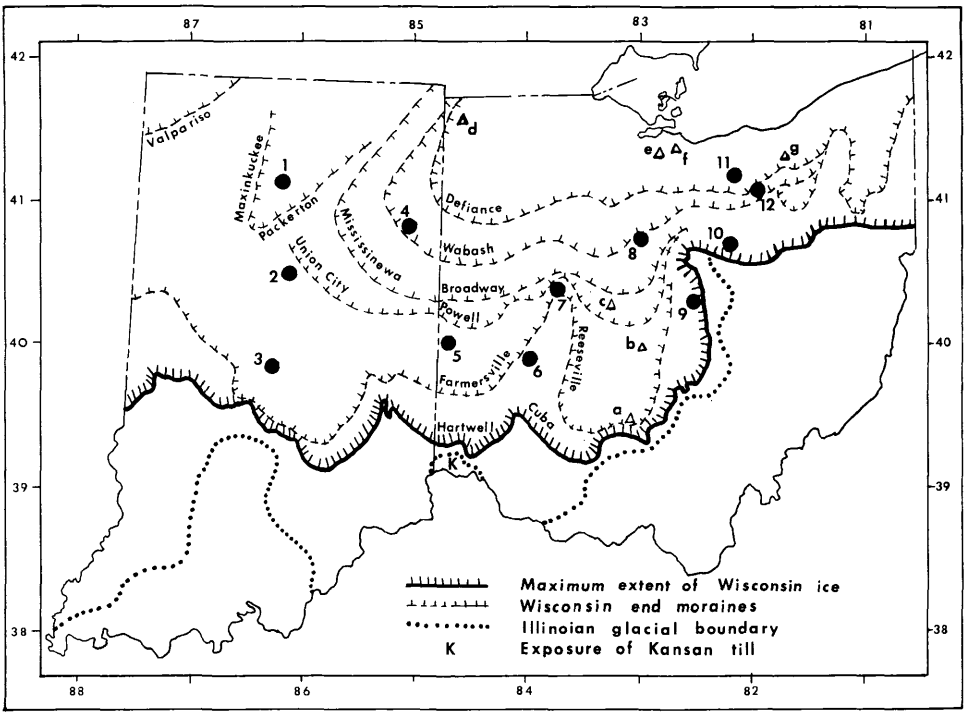

FIGURE 2. Map of Ohio and Indiana showing approximate glacial boundaries (moraines), location of pollen profiles and radiocarbon dates. Authors and citations in text.

maximum at 700 cm, shown in diagram SL–1A (Plate I) is therefore correlative with the Two Creeks warm time. The Valders ice advance may therefore be represented in the Silver Lake pollen sequence by a slight resurgence of spruce pollen at 640 cm, but there is no clear evidence of climatic cooling.

Pollen zone 3a. The virtual extinction of such boreal forest elements as spruce, fir, pine, and aspen pollen, and the abrupt rise of oak and hickory pollen, which marks the pollen zone 2/3 boundary, is found in almost all pollen profiles from northeastern North America. The initial maximum of elm and *Carpinus-Ostrya* pollen with the rising oak curve must indicate a moist and warming climate. The maxima in beech and walnut pollen at the top of zone 3a indicate a warm-moist maximum in the postglacial history of Silver Lake.

The pollen spectra from the lower part of zone 3a are quite similar to surface pollen spectra recovered from lakes in southeastern Ontario in the Southern Great Lakes-St. Lawrence Forest Region. The pollen spectra from the upper part of zone 3a are statistically indistinguishable from those found immediately below the European weed indicators (zone 3c) in Silver Lake.

Pollen zone 3b. The boundaries of this pollen zone are marked by a minimum in beech pollen and by an increase in nonarboreal pollen types (Plate I). A modest increase in the frequencies of *Artemisia* cfr. *ludoviciana* and in Chenopod-Amaranth pollen can also be seen in this zone (Plate II). A maximum in hickory pollen is also found in zone 3b (OWU–79, 3600±212y. B.P.) and can best be recognized in the AP diagram (Plate III).

A climatic somewhat drier and warmer than at present is inferred from these data. It is not possible, from pollen evidence alone, to determine whether a shift of this kind implies warmer conditions, drier conditions, or some combination of both. Whatever the cause, this portion of the core reflects the Xerothermic Interval described by Sears (1942c) and represents the eastward extension of prairie into Ohio, Indiana, and southern Michigan discussed by Transeau (1935, 1941).

In analyses of several bog and lake deposits in Indiana and Michigan, Potzger (1946) did not find grass pollen in amounts greater than that found in the Silver Lake, Ohio, profile presented here. Williams (1957) found no marked period of NAP dominance in his analysis of Medway Bog in Clark County, Ohio (fig. 2, no. 9).

North and west of the Medway bog site, however, Kapp and Gooding (1963) found evidence of prairie conditions in their analysis of Sunbeam Prairie Bog in Darke County, Ohio (fig. 2, no. 10). The profile from Sunbeam Prairie Bog shows high percentages of grasses (10%), sedges (30%), and composites (20%) in the upper levels of the deposit. Although the section is truncated at the top by fire and agricultural disturbance, no European weed pollen were found in the analyses described here.

In a similar deposit in north-central Indiana, the Wells Mastodon site (fig. 2, no. 11), Ogden (Gooding and Ogden, 1965) found a maximum of Chenopod-Amaranth (10%), grass (40%), and sedge (8%) pollen. The sum of nonarboreal pollen types in this site is 70%. Although this sequence is also truncated at the top, both the Wells site and the Sunbeam Prairie Bog site indicate a replacement of oak-hickory-beech (zone 3 in Silver Lake) by prairie pollen types.

Pollen zone 3c. The division of this pollen zone into "c" and "d" recognizes the devastating effect of forest clearance and European agricultural practices upon the pollen record of Silver Lake. Coincident with the spectacular maximum of *Ambrosia*-type pollen in the upper 70 cm of the core is the presence of *Plantago major* and *Rumex* cf. *acetosella* pollen. These highly distinctive pollen types were introduced with European agriculture. Chenopod-Armaranth pollen also shows a maximum in zone 5a.

The zone 3c/3d boundary is drawn at the rise of beech pollen and the decrease of nonarboreal pollen shown in Plate I. The pollen spectra associated with zone 3c indicate a rich mesophytic forest assemblage, which includes oak, hickory, beech, ash, elm, maple, walnut, sweet gum, cherry, and basswood. One can readily imagine that the drier uplands were covered with an oak-hickory assemblage, and that the north slopes and protected areas supported a beech-maple forest association. While the actual composition of the pre-European forests must remain as speculation, certainly the pollen types requisite for such an assemblage can be demonstrated.

Rapid settlement of this region by European colonists did not begin until shortly after the American Revolution (ca. 1780). It would appear from the pollen record that the principal pollen type to be affected was oak, which is not surprising in view of the desirability of this wood for framing timbers and house

construction. Whether the decrease in beech pollen is due to actual removal of the tree, or whether opening of the forest canopy resulted in decreased flowering by exposure of the forest floor to increased evapo-transpiration rates, is debatable.

Hickory responded to the opening of the canopy by increased pollen production and probable seeding-in. It is tempting, but quite inconclusive, to suggest that the minor decline in walnut pollen might reflect an improvement in taste among the settlers, and the replacement of serviceable oak furniture with more finely finished walnut.

It is not apparent that the forest of pre-Revolutionary days differed very much in species composition from that of the modern woodlands. Certainly, the actual number of each kind was quite different, but the same pollen types are found in pre-Revolutionary pollen spectra (Plate I, 80 and 100 cm) as are found in the present surface pollen spectra (Plate I, 0 and 10 cm).

The maximum in Rosaceae shown in Plate II undoubtedly includes the pollen of the wild black cherry trees found in the Camp Willson woodland. Although there is a column labelled "*Prunus*" in Plate I, it must be pointed out that identification of this pollen type is possible only in exceptionally favorable circumstances of slide preparation and position of the pollen grain. In other words, positive identification of "*Prunus*" indicates the unquestioned recognition of that pollen type, but the lack of such generic identification may simply mean that it was impossible to determine the genus, and that the pollen was therefore lumped under "Rosaceae."

Despite the fact that less than 20% of the land within a five-mile radius of the lake is in woodland, more than 50% of the pollen in the surface muds of the lake are from trees. Cereal pollen, which were determined as all grass pollen grains larger than 80 μ, extend below the levels associated with European cultivation. This may indicate some pre-European agriculture on the part of resident Indian tribes in the area. It could be expected that, since Indians are known to have made use of Chenopods and Amaranths for food, and that fire was frequently used for clearing, evidence of this would be recovered in the profile. An insufficient amount of material was studied to explore this possibility, but further work on characterization of Indian/European forest disturbance is in progress.

RELATION OF SILVER LAKE POLLEN SEQUENCE TO OHIO MORAINES, AND PROBABLE AGE OF DEPOSIT

The pollen sequences discussed in this paper are shown in relation to the major moraine systems in Figure 2. With the exception of the Wells Mastodon Site in north-central Indiana (Gooding and Ogden, 1965) and the Sunbeam Prairie Bog site in west-central Ohio (Kapp and Gooding, 1963), all of the pollen sequences show a similar history. A major oscillation may be found near the base of each of these profiles. From careful study of each of these sequences, it is concluded that all of these deposits were initiated during the same climatic interval, and that no large time span separates the basal organic sediments of these deposits.

Although several major morainal systems intervene between the pollen sequences of the group of older sites (Bacon Swamp, Kokomo Bog, Medway Bog, Silver Lake, and Long Lake Bog) and the group of younger sites (Jeff Bog, Bucyrus Bog, Granger Bog, and Camden Bog), the principal difference seems to be a longer basal spruce period in the more southern bogs.

Numerous radiocarbon dates from glacial and non-glacial materials in Ohio (Goldthwait, 1958; Forsyth, 1961; Ogden and Hay, 1964, 1965) indicate that the maximum extension of the Wisconsin ice sheet in Ohio occurred between 18,000 and 20,000 years ago. Radiocarbon dates from postglacial materials in northern Ohio indicate that the northern part of the state became ice-free between 12,800 and 14,300 years ago.

It therefore seems probable that each of these deposits began during the glacier

retreat which permitted the establishment of the Two Creeks Forest Bed in Wisconsin, and that the oscillation recorded in each of these sequences is correlative with the Valders ice readvance, which overwhelmed the Two Creeks Forest Bed.

An age of 11,000–14,000 years is inferred for the initiation of the Silver Lake deposit, based on a minimum age from Y–526, 11,480±160 years, B.P. from the Northern Lights Shopping Center, Franklin County, Ohio, a maximum age from W–198, 14,300±450 years, B.P. from Edon, Williams Co., Ohio, on the Ohio Turnpike, and the sedimentation rates in Silver Lake calculated from C–14 dates.

TABLE 3

Location of pollen sites and radiocarbon dates shown in figure 1

Pollen site no.	Name	Location	Author
1	Wells Mastodon site	Richmond Co., Ind.	Gooding and Ogden, 1965
2	Kokomo Bog		Potzger, 1946
3	Bacon Swamp		Engelhardt, 1960
4	Jeff Bog		Potzger, 1946
5	Sunbeam Prairie Bog	Darke Co., Ohio	Kapp and Gooding, 1963
6	Medway bog	Clark Co., Ohio	Williams, 1957
7	Silver Lake	Logan Co., Ohio	Ogden
8	Bucyrus Bog	Crawford Co., Ohio	Sears, 1930
9	Torren's Bog	Knox Co., Ohio	Ogden
10	Long Lake Bog	Ashland Co., Ohio	Potter, 1947
11	Camden Bog	Lorain Co., Ohio	Potter, 1947
12	Granger Bog	Medina Co., Ohio	Potter, 1947

Radiocarbon site no.	Name and location	Lab. no.	Age
a	Adelphi, Ross Co., Ohio	OWU–76	17,290±436
b	Northern Lights, Franklin Co., Ohio	Y–526	11,480±160
c	Liberty Twp, Delaware Co., Ohio	OWU–83	14,780±192
d	Edon, Williams Co., Ohio	W–198	14,300±450
e	Bellevue, Sandusky Co., Ohio	Y–240	12,800±250
f	Parkertown, Erie Co., Ohio	W–430	12,920±400
g	Cleveland, Cuyahoga Co., Ohio	W–33	13,600±500

SUMMARY

A pollen profile from a sediment core 8.90 m in length is described from Silver Lake, Ohio. The lake basin is located in the Farmersville moraine system in the axis of the Miami and Scioto lobes of the Wisconsin ice sheet. Although the age of the lake basin is unknown, radiocarbon dates from glacial and non-glacial deposits elsewhere in Ohio indicate that an age of 11,000–14,000 years, B.P. is appropriate for this part of Ohio.

On the basis of evidence detailed in this paper, the following generalizations seem justified:

1. Although no evidence of a plant succession from a treeless tundra was found, the presence of open country herbaceous pollen types, such as *Artemisia* cfr. *borealis*, *Saxifraga oppositifolia*, and *Polygonum bistorta*, together with relatively high amounts of sedge (6%) and grass pollen (15%), indicate the presence of open ground initially in the vicinity of the site.

2. Comparison of pollen spectra throughout the core with pollen spectra recovered from surface muds of Canadian lakes indicates that forests similar to those now found in the Northern Clay Belt region of Ontario prevailed during the latter part of zone 1 time.

3. A sharp increase in nonarboreal pollen, and the presence of open-country indicators such as sedge and grass pollen in zone 2 is inferred to represent the Two Creeks warm time in central Ohio.

4. No modern equivalent vegetation type has been found for pollen zone 2 from Silver Lake, Ohio.

5. The pollen spectra at the base of zone 3 resemble the modern pollen flora of lakes in the southern Great Lakes–St. Lawrence forest region of southern Ontario.

6. The Xerothermic interval described by Sears can be recognized by the presence of warm-dry indicators such as *Artemisia* cfr. *ludoviciana* and Chenopod-Amaranth pollen in zone 3b at a C–14 age of 3600±212 (OWU–79). The beech pollen curve, with a distinct minimum at the level of OWU–79 is indicative of drier conditions than the periods preceding or following.

7. The pollen spectra of zone 3c indicate a rich mixed mesophytic forest community consisting of oak, hickory, beech, maple, walnut, and ash.

8. The catastrophic effects of forest clearance and European agriculture is evident in the presence of European weed types such as *Plantago major* and *Rumex* sect. *acetosella*, and in the dramatic increase in *Ambrosia*-type pollen in the upper 70 cm of the core. Other agricultural indicators recognized in the pollen spectra are *Zea Mays* and *Cirsium* cfr. *arvense*.

9. The conclusions of Voss (1933, 1937) and Fuller (1935) that there is no record of alternating moist and dry periods in midwestern pollen profiles is rejected on the basis of evidence detailed in this paper.

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PLATE I. Diagram SL–1A. Total pollen diagram of core SL–1. All pollen types presented as a percent of total land plant pollen.

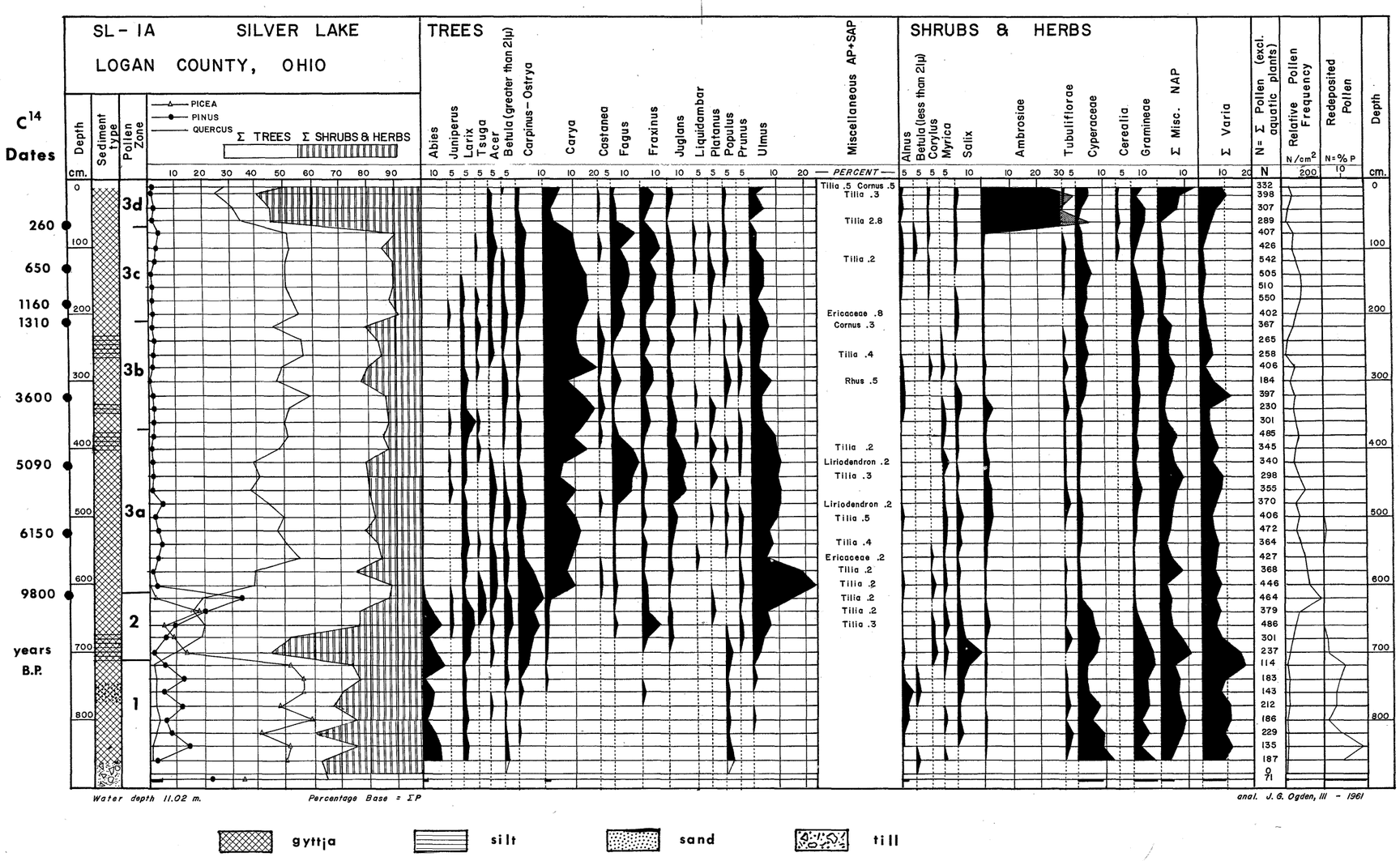

PLATE II. Diagram SL–1B. Nonarboreal pollen and non-pollen microfossil diagram. Loss on ignition and carbonate content shown at left.

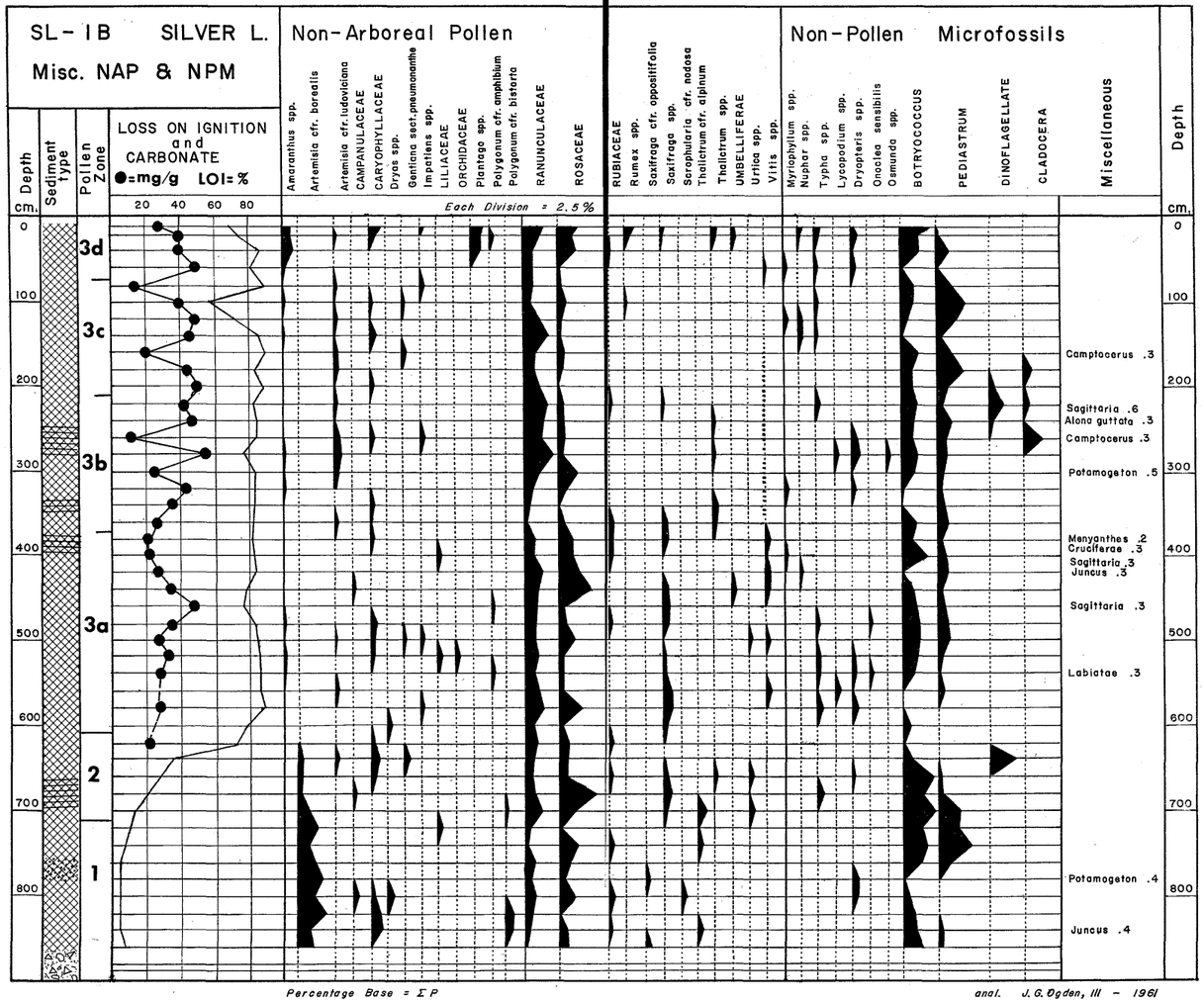

PLATE III. Diagram SL–1C. Arboreal pollen diagram. All pollen types presented as a percent of arboreal pollen only.